§7. Status of Negative-Ion-Based Neutral Beam Injection System of LHD

Kaneko, O., Takeiri, Y., Tsumori, K., Oka, Y., Osakabe, M., Ikeda, K., Nagaoka, K., Kondo, T., Kawamoto, T., Sato, M.

In every year, reforming of NBI system components is carried out during the maintenance period between the LHD experimental campaigns to improve the performance of negative ion sources or the reliability of the injection system. In order to get the basic data necessary for improvement, an idea is tested by small scale ion source at the Test Stand or the injector itself is operated during an off-machine time of LHD. These R&D efforts were rewarded by increasing the injection power year by year. After the successful results of 10.3 MW injection in the sixth campaign in 2002, which was mainly due to the power up of BL-1 by adoption of multi-slit ground grids in the ion sources, we tried to optimize the operating condition to increase the port-through efficiency. This is important for the multi-slit ion sources because the minimum beam divergence is obtained under the different conditions between vertical and horizontal direction. We also made an effort to increase the ion current since the beam energy had already reached the maximum value.

Figure 1 shows a summary of injected port-through beam power, and powers for three beamlines (BL-1, -2, and -3) during the last (seventh) experimental campaign of LHD in 2003. The port-through power was evaluated by measuring the heat load on the beam facing armor plate on the wall of LHD vacuum vessel. It is seen that the power gradually increases through the campaign, and there are some blanks that were made by various troubles occurred in NBI.

At the start of this campaign, problems occurred both in BL-1 and BL-2 that the frequent breakdowns in the ion source was not relieved even after usual conditioning process, and the beam energy stayed at low level. It was found that the grid became dirty and it looked like to be polluted with oil or some organic compound. In both beamlines, the grids of ion sources had been mended at the manufacturers, and it is supposed that the cleanup after machining was not enough. After careful cleaning, the voltage withstanding was recovered.

Small water leaks still occurred in the cooling channel of grids of ion sources, and they interrupted the operation. However, two other big water leaks occurred in this campaign and the experimental schedule was altered. One is a water leak in the beamdump of BL-1 which is made of swirl tube array. This trouble stopped the operation of BL-1 for a long period. The tube melted and a hole was made at the unexpected point where the calculated beam power is not very high. The reason of this phenomenon is not clear yet. The other water leak occurred in the drift tube of injection port, where the molybdenum protector covers the wall and the cooling water pipes on it. It happened when the molybdenum block was heated and the connecting bolt was melted. Then the block moved and the cooling water pipe behind was exposed to the beam. This excess heat load on the molybdenum block occurred because the vertical beam divergence was still large in the multi-slit grid system. This should be corrected until the next campaign.

As a whole, however, the port-through power increased through a campaign period (4 months) as seen in the figure, and the maximum power reached 13.1 MW. All the beamlines recorded their highest power in this campaign (5.7 MW for BL-1, and 4 MW for BL-2 and BL-3). Among them BL-1 went over its specification of 5 MW by 180 keV beam, and 5.7 MW was injected for 2 seconds. This power up (4.4 MW in 2002) was due to the increase in the negative ion current which was done by careful control of the cesium injection, and plasma grid temperature.

We will continue to make an effort increasing the port-through power to the specification value of 15 MW.

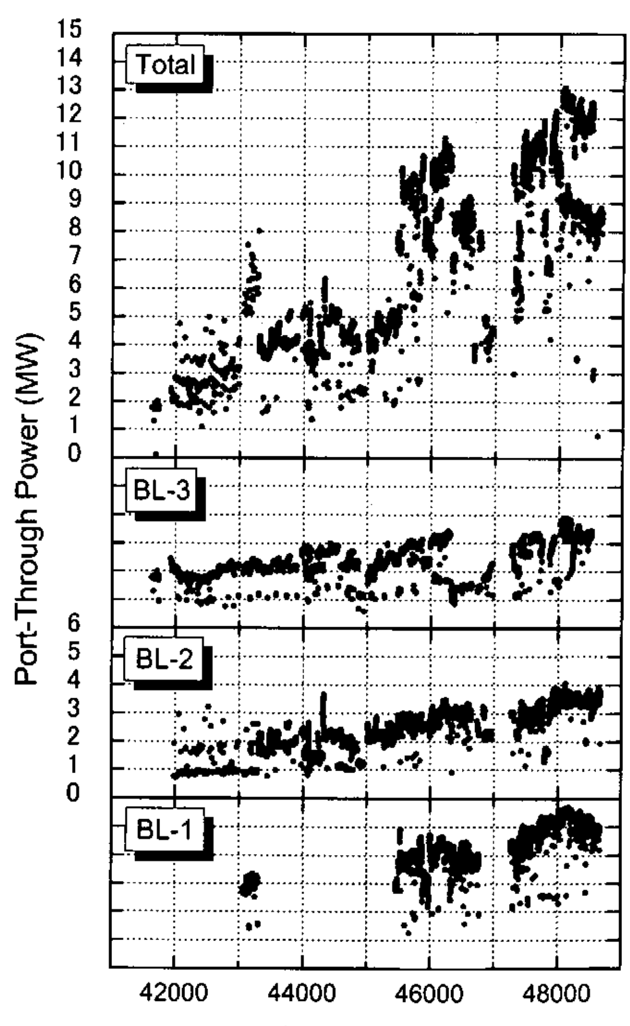

Fig.1. Summary of beam power during the seventh campaign.